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LONG RANGE SPOIL DISPOSAL STUDY. PART V. SUBSTUDY 4. PUMPING TH--ETC(U)

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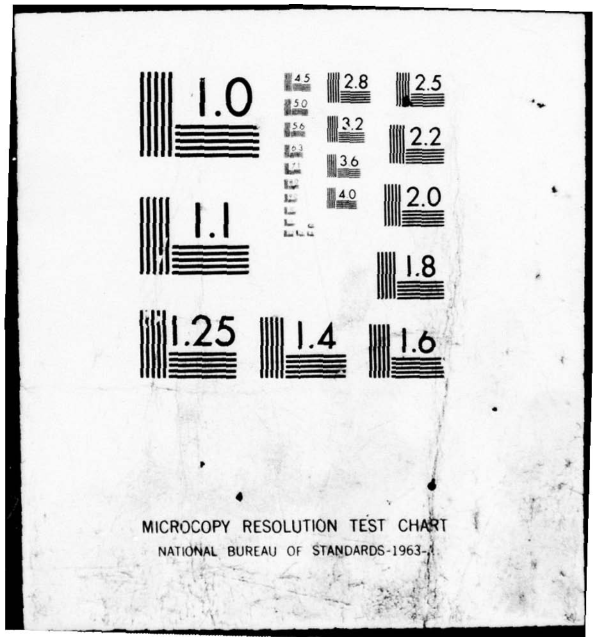
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PART V.

SUBSTUDY 4.

PUMPING THROUGH LONG LINES.

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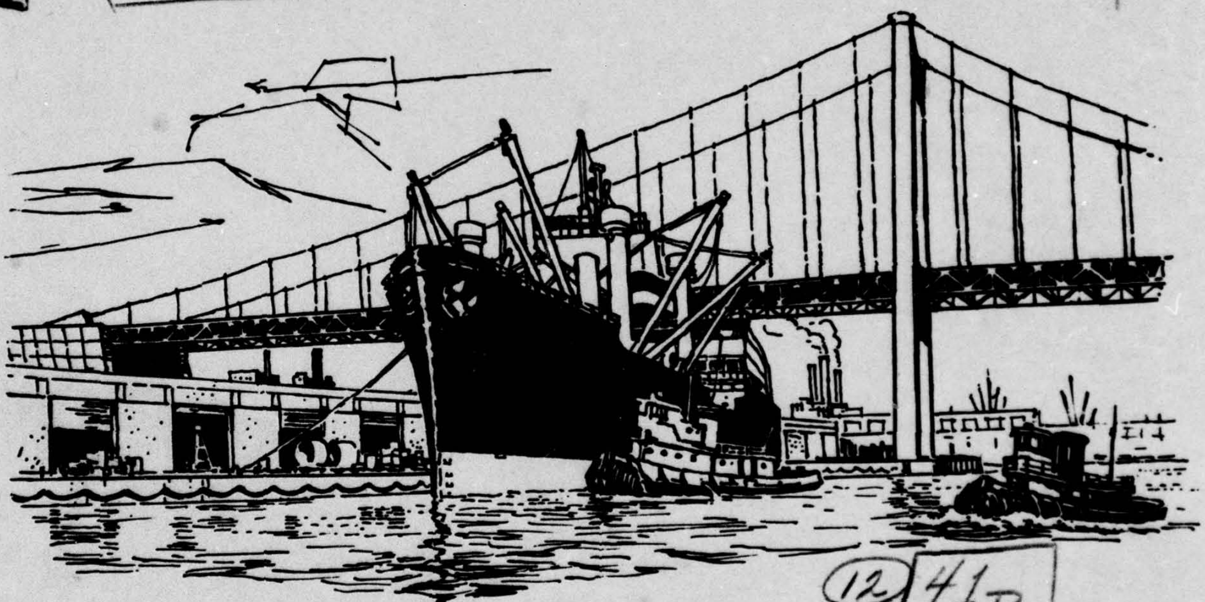

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NORTH ATLANTIC DIVISION

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FOREWORD

This study and report were completed as one of the six Sub-Studies which comprise the overall "Long Range Spoil Disposal Study" in the Delaware River. The overall study was conceived and initiated by the Philadelphia District Engineer, Colonel W.W. Watkin, Jr., who had been directed to such an effort by the Chief of Engineers. The Project Manager for this Sub-Study was Mr. Keith Lawrence, who had much assistance from Mr. Adolph Mohr, P.E., and assistance from Mr. Lewis Caccese, P.E.

The "Long Range Spoil Disposal Study" consists of seven parts which are listed below. Part I which is "General Data on the Delaware River" contains detailed background data which is pertinent to this report. This report is Part V of the overall study.

The study is divided as follows:

PART I - GENERAL DATA ON THE DELAWARE RIVER furnishes the information and data on the Delaware River which is pertinent to the entire study.

PART II - SUB-STUDY 1, SHORT RANGE SOLUTION evaluates the remaining disposal area capacity in terms of its remaining life, and to recommend any further desirable and acceptable disposal area developments.

PART III - SUB-STUDY 2, NATURE, SOURCE, AND CAUSE OF THE SHOAL develops in depth the basic data as to the nature of the Delaware River shoals, their sources, and their causes. It is hoped that this knowledge may reveal new concepts for the better control of shoals.

PART IV - SUB-STUDY 3, DEVELOPMENT OF NEW DREDGING EQUIPMENT AND TECHNIQUE identifies the best in dredging plant and dredging technique for Delaware River dredging maintenance tasks now and in the future.

PART V - SUB-STUDY 4, PUMPING THROUGH LONG LINES examines the merits of transporting dredged materials many miles through pipelines.

PART VI - SUB-STUDY 5, IN-RIVER TRAINING WORK determines the potential of training works for control of shoaling. It involves considerable model testing.

PART VII - SUB-STUDY 6, DELAWARE RIVER ANCHORAGES considers the effect of man-made anchorage on shoaling problems and the merits of alternate solutions.

SUMMARY

This study inquires into the feasibility and practicality of pumping dredge spoil long distances. The purpose of the proposed operation is to deliver dredged spoil by pipeline to locations far removed from its origin.

The study concludes that transport of dredged spoil by pipeline over long distances is feasible technologically and will cost about $0.01/cu. yd. for each mile the spoil is transported. It is acknowledged that this transport cost exceeds the cost of transport of dredge spoil by waterborne cargo carrier which is studied in Sub Study No. 3. Therefore, the study concludes that the best promise for utilizing the discussed technique would be in connection with a large capacity inland source which would be enhanced by the dredged spoil.

INTRODUCTION

BACKGROUND

The Delaware River, and particularly the Philadelphia Port Area, constitutes a major port complex. Over 100,000,000 tons of waterborne commerce move through the Port of Philadelphia each year. This commerce relies in large part on the man made 40-foot channel which is constantly subjected to regular shoaling. Therefore, maintenance of the 40-foot depth requires constant dredging. It results that 7,000,000 to 8,000,000 cubic yards of shoal material are dredged from the Delaware River channel and placed ashore each and every year. A characteristic of this dredging is that, for the most part, shoaling, and the subsequent dredging, takes place in repetitive locations and reasonably predictable rates.

The most significant shoaling areas are: Marcus Hook, Pa., Philadelphia, Pa. and New Castle, Delaware. These areas represent the majority of the dredging requirements necessary to maintain the Port of Philadelphia. From this it is apparent that any better approaches to the dredging and spoil disposal problems in these areas will have relevance to the dredging work in the entire river.

Since the shoaling occurs primarily at specific locations, disposal areas for the dredged spoil in these vicinities are of key importance, The supply of disposal areas in these critical areas is severely limited because of past use of the most desirable areas and the physical development of the remaining areas. Plate 1 shows the most significant shoaling areas of the river and the related disposal areas.

STATEMENT OF THE PROBLEM

This study was conceived in view of:

1. The anticipated continued need to dredge in the repetitive shoaling areas.

2. The foreseeable consumption of the disposal areas relatively close to shoal areas.

3. The increasing use of pipeline for transport of materials.

4. The successful experience in the Delaware River of routinely pumping dredged material for disposal by direct pump-out of hopper dredges for distances of 3 miles.

The goal of this study is to examine the technical and practical feasibility, and the advantages which might accrue, of pumping dredge spoil (25-50 miles) from the intensely developed port complex where disposal areas have become filled to locations where the dredge spoil is at least acceptable, if not clearly advantageous.

PUMPING SOLIDS THROUGH PIPELINES

Pumping of liquid and gaseous products through pipelines for thousands of miles is commonplace. In recent years a variety of solid materials have been transported many miles through pipe lines while suspended in a fluid. The successful installations in this country are numerous. An excellent insight into the variety of pipe line installations for solids, their uses, and the practical aspects of designing and operating a pipe line are contained in "The Transportation of Solids in

Steel Pipelines'' published by the Colorado School of Mines Research Foundation, Inc. This text also includes a valuable list of references on the subject. This book was relied upon in developing the concepts for this study.

Installations transporting solids in pipe line in the United States which seemed analagous to the requirements of the problem were visited. Mr. Keith Lawrence and Mr. Adolph Mohr, representatives of the Corps of Engineers, visited the pipe line installations at the Noralyn Operation of the International Minerals and Chemical Corporation in Florida. This industry uses 20 inch pipe line to transport Phosphate Pebbles from mine to plant, distances of up to 29,000 feet. The installation confirmed the design parameters utilized in this report. The Watson Mine operation of Swift & Company at Fort Meade, Florida, and the Plant of Armour Agricultural Company, Bartow, Florida, were also visited.

Mr. Adolph Mohr, also visited Bos En Kalis, a Dutch dredging concern who design and operate dredging plant. They are world renowned and have had considerable experience in pumping sand long distances (8 miles) for land reclamation. Bos En Kalis personnel confirmed, in general, our concept on pumping through long lines. Some specific advice furnished was:

1. Solids should enter a pipe line from a hopper of at least 300 cubic yards capacity. The hopper should serve to receive the mixing water also and to prevent air entering the pipeline with the material.

2. Long discharge lines should be provided with water inlets at several places to clear plugs which might occur.

3. The largest particle size for long line discharge should be approximately 1 inch.

CONCEPT

REHANDLING UNIT

The concept of a long line disposal system starts with a semiportable rehandling unit (See Fig. I) which would be moved from disposal area to disposal area as required. Its purpose would be to empty out available disposal areas and inject the dredged material into a long pipe line. The material would then be pumped to a distant repository through the line with successive Booster Stations. The rehandling installation would be sized to accommodate the amount of material removed from the Delaware annually. It would pump 24 hours/day at the lowest velocity which would keep the required amount of material in suspension, in order to keep power requirements and wear at a minimum.

It may be noted that the material is not picked up from the disposal area by the first booster station. An endless chain bucket is used for that service. The dredged material is delivered into a hopper in order to maintain a constant supply of material to the pump. This prevents fluctuations of the hydrodynamic forces throughout the pipeline, which would cause variations in slurry velocity and density.

The unit would handle, on any given day, relatively uniform sizes of material. This results from the fact that the hydraulic dredging process which placed the materials in the disposal area in the first instance grades the dredge spoil by depositing the the heaviest at the pipe discharge while the finest particles are carried to the vicinity of the sluice. This also means that the large particles (over 1 inch in size) at the end of the pipe discharge can be avoided and not injected into the long line. They can be removed by more conventional means. as their relative quantity is quite small.

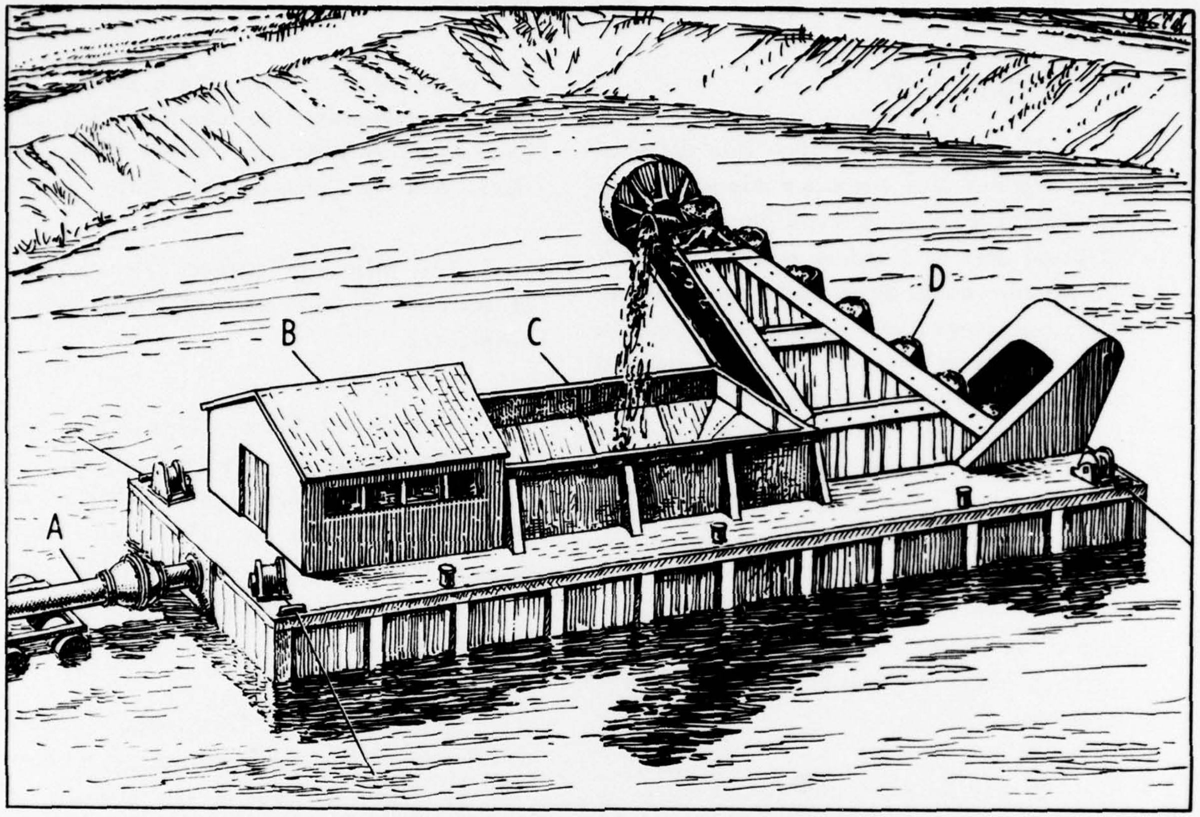
The following methods for pick up of material by the rehandling unit were considered.

1. Clamshell bucket: This method has the advantage of simplifying positioning of the rehandling unit due to the working arc of the pickup unit. However, calculation demonstrates that the size of this pickup unit required becomes extremely large for the quantity to be handled.

2. Dredge pump: This method is well developed but has the disadvantage of diluting the solids excessively for the job at hand. In other words, it is believed that its discharge will not settle out the material to be rehandled readily enough to achieve the mixture control desired.

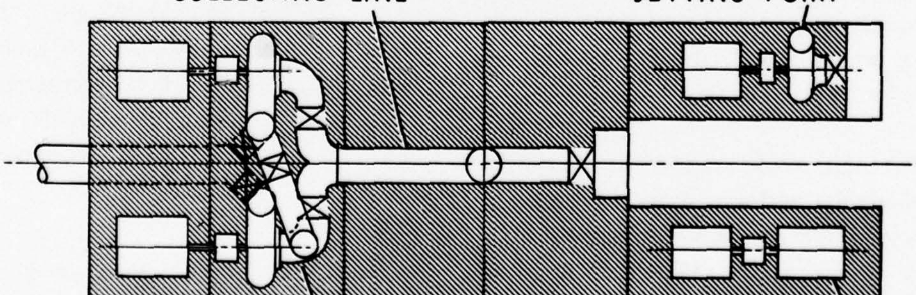
3. Endless chain bucket: This method which has considerable use in ore mining has the advantage of delivering the material at close to insitu density. It would also be relatively small in size and power requirement.

The endless chain bucket material pickup unit has been selected as best for the application. It would be combined with a 300 cu. yd. hopper and the first booster station on a vessel. The combination forms the rehandling unit. Such units are in operation in Europe.



A-DISCHARGE LINE B-HOPPER DECK HOUSE C-HOPPER
D-ENDLESS CHAIN BUCKET PICKUP

COLLECTING LINE JETTING PUMP



FIRST BOOSTER STATION MOTOR & SPEED REDUCER FOR BUCKET DRIVE

EQUIPMENT PLAN BELOW DECK

Figure 1 - Proposed Rehandling Unit

Since the sole purpose of the rehandling unit is to remove material within the confines of a disposal area, it is envisioned that positioning equipment and floating pipeline associated therewith can be simple.

Design of a pipe line requires that criteria be established for velocity and maximum line pressure; pipe size; type, spacing, and arrangements of pumps; type of power; pipe quality, pipe instrumentation, etc. These are discussed in the following paragraphs.

VELOCITY

Pipe friction, and consequently horsepower requirements, will increase as the square of velocity. Pipe wear also increases with velocity. In view of this the optimum velocity is the lowest velocity which will reliably transport the solid matter. It has been assumed that 12 ft/sec. is the lowest velocity which will support the suspension of solids in dredged mixtures. The minimum acceptable velocity was further studied by field tests made in July 1966 on dredge discharge in the Philadelphia District. These tests indicated that at velocities of 12 ft/sec. particles up to 2 1/2 inch in diameter were successfully transported. At velocities below 12 feet/sec. a pronounced increase in the amount of material being transported along the bottom of the pipe was noted. From the above it was concluded that 12 ft/sec. should be the design velocity for a pipe line system for Delaware River silts. This is believed to be a conservative assumption. Actual practice may permit even lower velocities. Should this occur, the benefits of reduced power consumption and reduced wear would be realized. The detail of the July 1966 experimentation is contained in Appendix A.

PIPE LINE SIZE

The pipe line size for this task is determined as follows:

1. 7,000,000 cubic yards of material of an average insitu density of 1300 grams/liter must be removed from the Delaware estuary annually.

2. It would be rehandled in a pipe line at a mixture density of 1150 grams/liter and a velocity of 12 foot/sec as previously discussed. (The 1150 grams/liter has been chosen as a conservative value for no true precedent exists.)

3. The rehandling unit will work the equivalent of 300 days/year. Remainder of time is for moving rehandler unit between sites, contingencies, breakdowns, etc.

4. Absolute shoal quantity/sec. =

$$\frac{7{,}000{,}000 \times 27}{300 \times 24 \times 60 \times 60} = 7.3 \text{ cubic ft/sec}$$

5. Quantity of rehandled mixture/sec =

$$\frac{1300 - 1{,}000}{1150 - 1{,}000}\ (7.3) = 14.6 \text{ cubic ft/sec}$$

6. Required pipe area at 12 ft. velocity is $\frac{14.6}{12} = 1.2$ sq. ft.

7. A 16 inch dia. pipe has an area of 1.3 sq. ft. and is therefore selected for pipe size and pump size.

BOOSTER STATIONS

Booster stations would be of the two stage or double pump (connected in series) type, to reduce the amount of enclosures, electric power terminals, transformers (if applicable), etc. All booster stations would be indentical with the exception of the first one; the first one employs the same pumps and motors but differs in arrangement. The contemplated booster station is shown in Fig. 2. Other characteristics of the booster stations are as follows:

1. Booster stations would be designed to operate remotely, controlled from the rehandling unit.

2. Each booster unit consisting of pump, motor, bearing and sealing pump (if applicable) would be assembled on a common bed plate.

3. All booster units would be identical, but their pump housings would be rotated to have the discharge flange at different positions.

4. The design shown on Fig. 2 is for normal (two pump) operation and utilizes a maximum of identical components.

5. A fence around each land station, a portable hood over each motor and a small house to protect the main electrical equipment is believed to provide sufficient protection.

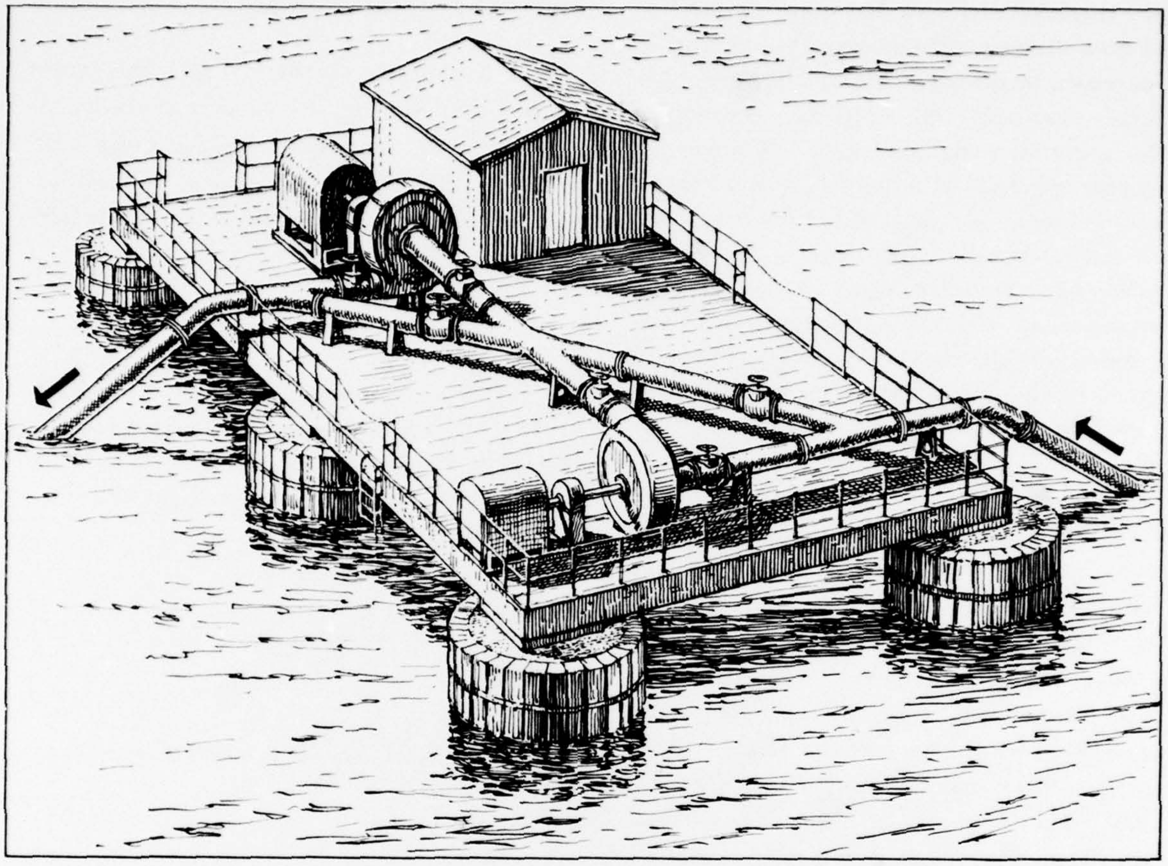
6. The pipe inlet and outlet from the enclosure are at the same elevation, but the pump-motor units comprising one station would not.

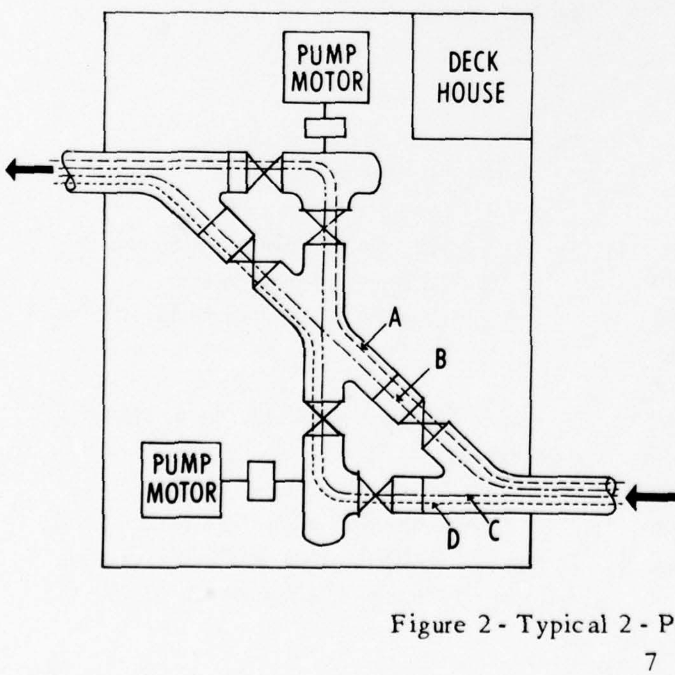
7. Electric power to operate the rehandling unit and all booster stations would be procured from commercial sources.

PIPE MATERIALS

Obviously, the service life of pipe would be a significant cost factor in a long line which would be carrying abrasive material. In view of this there was communication with all the major steel producers and pipe fabricators to identify the best material that could be obtained from the industry. A suggested requirement to them was for a pipe which would have sufficient life for the transport of 100,000,000 cubic yards of a 10 percent sand mixture.

The advice obtained from the Chief Metallurgist of the U.S. Steel Corporation,





POSSIBLE FLOW PATTERNS

A - UTILIZING 2ND STAGE PUMP ONLY
(REPAIR TO 1ST STAGE PUMP)

B - BYPASSING BOTH PUMPS

C - UTILIZING BOTH PUMPS IN SERIES
(NORMAL OPERATION)

D - UTILIZING 1ST STAGE PUMP ONLY
(REPAIR TO 2ND STAGE PUMP)

Figure 2 - Typical 2 - Pump Booster Station

Mr. Hugh Tombs, was that long service life is most economically obtained by purchasing increased thicknesses of standard steel pipe rather than using the additional dollars for the abrasion resistant steels. Abrasion resistant steels also bring the disadvantages of brittleness and lack of weldability which is characteristic of hard steels.. These disadvantages would be significant in the construction of a long pipe line. Mr. Tombs pointed out that use of abrasion resistant steel (such as T-1) could increase cost of pipe four times while only doubling the life of the pipe.

In order to evaluate all possibilities the Philadelphia District installed ten different sections of 28'' diameter pipe in its floating pipe line which is in daily use. These sections were installed adjacent to one another and represent the best recommendations which various manufacturers suggested. The installation was made April 1967. The pipe was in continuous service until September 1968 when it was evaluated. The results of this test is presented in Appendix D of this report.

LINE PRESSURE

The maximum line pressure which can be tolerated establishes the booster pump spacing and the thickness of pipe. A pressure of 200 lbs/square inch is the maximum line pressure which has been reliably utilized in dredging operations. The present development of pump packing and gland seals will not reliably tolerate pressures above 200 lbs/square inch where abrasive particles are encountered.

BOOSTER PUMP SPACING

A maximum pressure of 200 PSI determines the spacing of booster stations. A modern well constructed dredge pump will produce 100 PSI. Two pumps, in series, will therefore produce the 200 PSI limintlng pressure.

1. Based on computations:

Assume each pump creates a 100 PSI (231 ft) pressure differential, friction factor f = 0.02, and the effluent velocity is 12 ft/sec. Then, from the Darcy-Weisbach formula for calculating pipe length:

$$L = \frac{H \times D \times 2g}{f \times V^2} ;$$

$$L = \frac{231 \times 1.33 \times 64.3}{0.02 \times 144} = 6{,}860 \text{ ft. per pump}$$

2 x 6,860 = 13,720 ft. spacing for two pump booster stations.

Where: H = Head Pressure in ft
f = friction factor
L = Length of Pipe in ft
V = Velocity of effluent in ft/sec
D = Diameter of pipe in ft
g = Gravitational acceleration in ft/ sec^2

2. This is verified from previous experience:

The rehandler NEW ORLEANS, and Dredges COMBER AND GOETHALS were designed to pump a distance of 20,000 ft.

with two pumps in series; however, experience at Darby Creek, Pennsylvania indicated that 15,000 ft. is close to the practical limit. The velocity at this line length was estimated to be less than 12 ft/sec. since the pipe at times did not flow full at the end.

3. Further verification is found on pages 72 and 73 of the book "The Transportation of Solids and Steel Pipelines",[1/] examples 29 through 32 are similar to our proposed line. These examples are further detailed on pages 102 through 105 of that reference. They indicate that, at 12 ft/sec. velocity, the friction head averages 3.5 ft/100 ft. of pipe. Assuming that each of the contemplated pumps will create 100 psi (231 ft) pressure differential, this friction head will permit pumping through a distance of 2 x 231 x 100/3.5 = 13,200 ft.

4. A pump manufacturer recommended 16,500 lin. feet between booster stations. See letter from Brann & Cary, Inc. of 2 November 1966 inclosed as Appendix B. This more generous spacing, than indicated by 1, 2, and 3 above has further dredging support in the actual use of 16" dredges. For example the 16 inch Dredge ERIE of American Dredging Company, using a single pump, pumped through 10,000 ft. of line at Sea Isle City, N.J. in 1962 without difficulty. The pump was powered by a 1200 H.P. engine.

The foregoing indicates that approximately 15,000 feet is the limit for a double-pump line. A 12,500 foot spacing is utilized in this concept to permit the latitude that 1 in any group of 4 adjacent pumps may be out of service without shutting down production. (Note the valving and flow lines in Fig. 2 which will permit this).

DREDGE PUMP SEALING WATER

No installations are known where abrasive material handling pumps operate without sealing water. It is therfore concluded that a source of sealing water has to be provided. Plans are to secure this water by means of a gland sealing water pump (or pumps) at each station, taking suction from a well or the river, or by means of a common large gland sealing water pump delivering water to each station through a pipeline along the dredge discharge line.

POWER PLANT

Electricity is accepted as the likely source of power for any long line installation in this area. This selection is made in view of its ready availability, acceptable cost, and the consideration that transmission line right of way may become the logical right of way for a proposed pipeline. Similar arguments can be made for use of gas. If a dredge line were to be installed along the right of way of a natural gas line, gas turbines would become most practical as prime movers.

A.C. power is suitable for booster stations. Pumps would be operating at relatively constant load and speed. A.C. motors which provide 850 absorbed horse power for each pump would be required at each station. There would be the associated switch board, power terminals, circuit breakers, starting devices and transformers at each station. (Transformers may be omitted if the motors can be designed to

[1] The transportation of solids in steel pipelines by Colorada School of Mines 1963.

operate at the available voltage). It should be noted that special precaution must be taken against electrolysis in the pipelines where they lie parallel to power transmission lines.

LINE INSTRUMENTATION

It is envisioned that the rehandling unit would be manned but that all booster stations would be unmanned. The unmanned stations would be instrumented to the rehandling unit to communicate operating conditions at the station. All operations at each booster station would be remotely controlled from the rehandling dredge. A control system based on radio and telephone lines is envisioned. Such a system has been discussed with The Bell Telephone Company of Pennsylvania. It is feasible and inexpensive. Initial specialized equipment would be paid for by the Government. Use of telephone lines would be billed monthly. Maintenance of the entire system would be performed by the Telephone Company under a maintenance contract.

OVERALL SCHEME

Fig. 3 is a representation of an overall scheme. This figure shows an installation wherein an upriver disposal area would be emptied into a downriver disposal area via a pipe line which has been laid on the bottom of the Delaware River. The installed pipe line could just as well be across country. It can be seen from Fig. 3 that the proposed scheme has the characteristic of not affecting nor altering the means of dredging nor transporting dredged material to the closest disposal area.

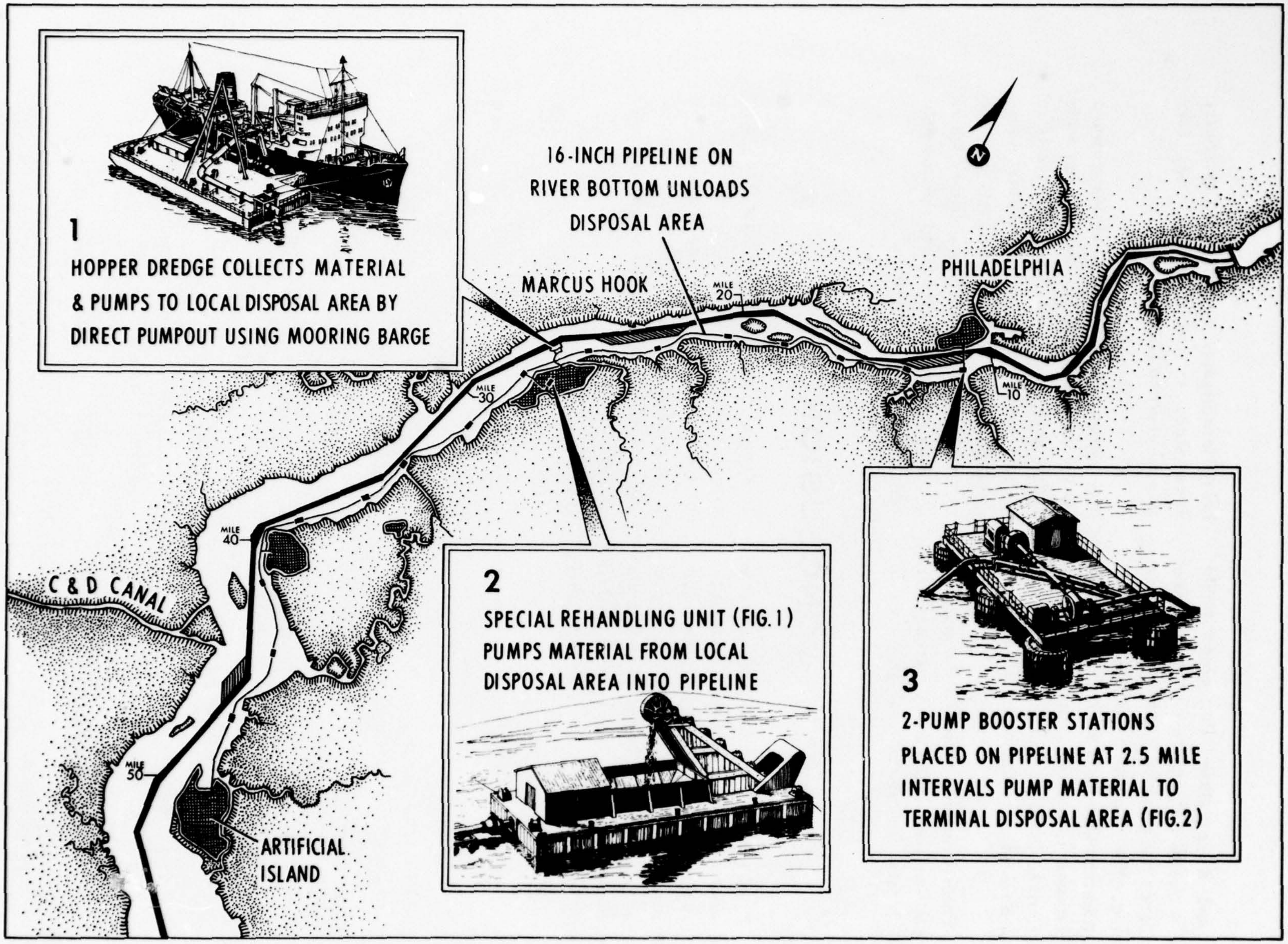
COSTS

Appendix C is the cost estimate for installation of a 100,000 foot line. It will be noted that wear factors have been based on actual experience data. From the estimate it can be seen that dredge spoil can be transported for about $0.01 per mile per cubic yard at 1967 price levels based on an operation which would move 7,000,000 cu. yards annually.

DISPOSAL OF SPOIL

The above costs indicate that the conceived long line (25-50 mile) has a tolerable cost if a site is available for the pumped fill. The problem therefore, is one of locating a suitable depository for the spoil. It is evident that such an area would have to be one where the fill would be acceptable, would serve a useful purpose, and would have no deleterious side effects. Investigations have been made and are continuing in this direction.

Extensive coordination and discussion has been held with the Bureau of Mines to ascertain whether pumping of dredge spoil into abandoned mines in the Scranton,



A Dredging Scheme for Delaware River

Figure 3

Pa., and Wilkes Barre, Pa., areas would serve a useful purpose in combating mine subsidence and mine fires. The results were negative. The Bureau of Mines believed their traditional methods were more suitable and economic in achieving their objectives, based on the large cost of moving material 100 or more miles to the mine fields.

The potential for moving the material by pipe line onto large sandy acreages in South Jersey for agricultural purposes is being investigated at Rutgers University. This study is continuing and may take several years to complete.

Some reconnaissance of State-owned land in southern New Jersey has been made and is being continued. The objective is to identify large parcels of real estate where the deposition of dredged spoil may be made in very large volume under conditions where the land will be enhanced and the disposal will be generally acceptable.

CONCLUSION

It is feasible and practical to move large amounts of dredge spoil great distances by pipe line. Such an operation would permit emptying the limited disposal areas which are available for dredge spoil in highly developed areas and thereby recreate their capacity for future use. However, this technique could only be justified under circumstances where there would be enhancement value by delivery of material to a far distant location, or when such disposal would be cheaper than any alternate means.

APPENDIX A

PUMPING THROUGH LONG LINES

NAPOP-P

SUBJECT: Pumping Through Long Lines

TO: Files

27 July 1966
AWMOHR/mar/4731

Purpose: The purpose of this investigation was to determine the minimum mixture velocity in a 20" pipe that will keep the solids in the mixture from settling out. Furthermore, we attempted to determine the friction head associated with this velocity and the distance 2 1/2" stones would travel from the end of the discharge line.

Background: This investigation is a prelude to the subject study and it will help to determine the size of the discharge line and the power requirement of the booster stations. In order to test, the short leg of the 28" shore piping at Killcohook was removed and replaced with two 20" lines. Both of these lines were connected as shown on Inclosure 1. One of the lines was selected as a test line. A tap connection was installed on top of this line near its beginning and its last two sections were adjusted to be horizontal.

Test Description: Several difficulties were encountered during the test requiring the writer and one or two other personnel to visit the test site three times (22 June, 11 July, 18 July). The principal difficulty stemmed from the fast build-up of the heavy material handled, which caused blockage of one of the discharge lines. Testing essentially started with both 20" lines fully open and then throttling of the test line until the desired discharge velocity was obtained. The pressure head at the beginning of the test line was then recorded. At the end of the pump-out phase the end of the discharge pipe was checked for settled solids. The discharge velocity was determined with a Gerig Stick and the pressure head with a mercury manometer as shown on Inclosure 1. The length and elevation change of the discharge line from the pressure tap to the end was determined with a measuring tape and a transit respectively. The dredging material was obtained by the COMBER predominantly from the C & D Canal and Bulkhead bar and consisted of sand with occasional stones up to 2 1/2" in size.

Test Results: From all the data collected, only the most significant two loads are discussed below:

The first load (Load No. 101, 7/11/66) was dredged at C & D Canal and discharged at a mean velocity of 12.5 ft/sec (velocity variations 12 to 13 ft/sec). The second load (Load No. 35, 7/18/66) was dredged at Bulkhead Bar Range and discharged at a mean velocity of 10 ft/sec. (Velocity variation 8 to 11 ft/sec). In both instances, the mean velocity was obtained by throttling the stream from a much larger velocity which then flowed for about 15 minutes until the end of the pump-out phase. It then decreased within about 30 seconds to zero.

Immediately prior to the first load an approximate 1/2" layer of material was noted in the bottom of the pipe. This sediment is believed to have formed during the brief period of previous pump shut off. At the end of the first load the same 1/2" layer of sediment was noted. Immediately prior to the second load the test pipe was completely clean as it had just been reassembled (necessary due to blockage). At the end of this load a three inch sediment was noted in the pipe. The sieve analysis of the sediment is attached.

It was noted that in the relatively heavy material, and low velocities at hand, the effluent is not a homogenious mixture, but carries nearly all of the solids near the bottom. A density sample, taken at the very bottom of the stream, had a density of 1577 gr/1 and a sample taken at the side 1108 gr/1. A sample secured from the top looked like cloudy water.

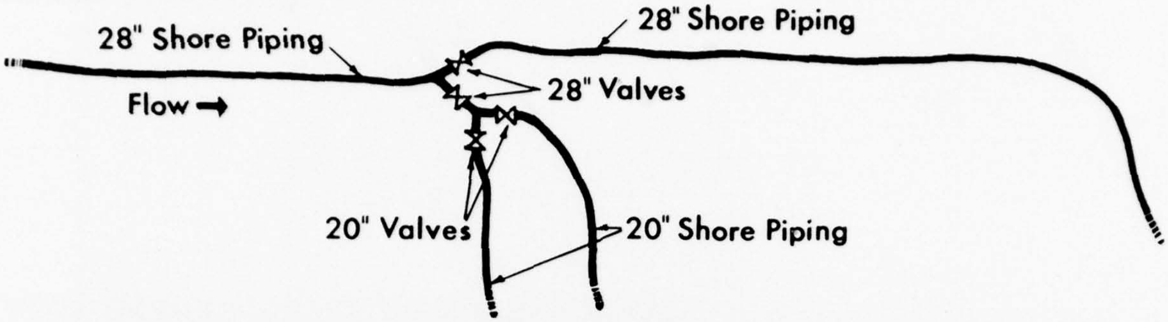
The pressure readings were erratic and resulted in erroneous friction factors.

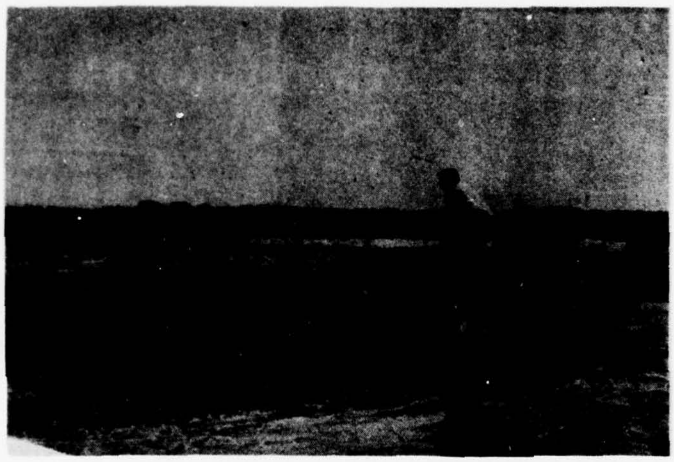
Stones up to 2 1/2" were found within a radius of 230 ft. from the discharge pipe.

Conclusion: The main conclusion drawn from the foregoing is, that a minimum flow velocity of about 12 ft/sec is necessary to keep coarse sand from settling out of a dredged mixture.

2 Incl
1 Sketch, Photos
  and Sand Gradation
2 ENG FORM 2087

A. W. MOHR
P. E.



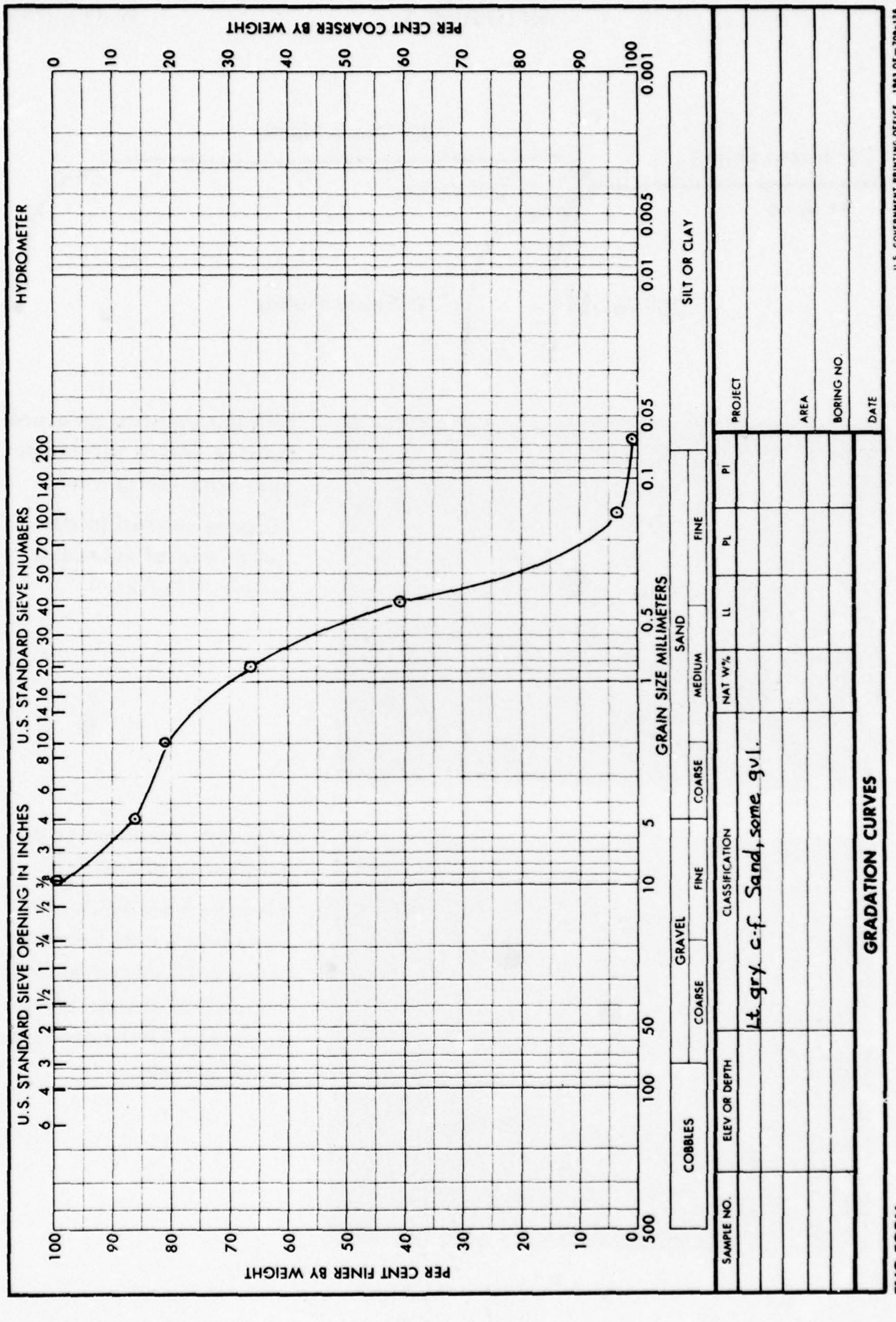


Effluent velocity measurement at end of discharge pipe with Gerig Stick.

20" pipe ceased to run full at end at velocities below 10 ft./sec.

Mercury manometer at beginning of test line.

Elevation between mercury levels and between lower mercury level and centerline of pipe were recorded. These readings were erratic.


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
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PER CENT FINER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
PER CENT COARSER BY WEIGHT
0 10 20 30 40 50 60 70 80 90 100
500 100 50 10 5 1 0.5 0.1 0.05 0.01 0.005 0.001
GRAIN SIZE MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
SAMPLE NO.
ELEV OR DEPTH
CLASSIFICATION
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LL
PL
PI
Lt. gry. c-f. Sand, some gvl.
PROJECT
AREA
BORING NO.
DATE
GRADATION CURVES
ENG FORM 2087
1 MAY 63
REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.
(TRANSLUCENT)
U S GOVERNMENT PRINTING OFFICE 1963 OF—709-126

APPENDIX B

LETTER, BRANN & CARY, INC.

BRANN & CARY, INC.

P. O. BOX 831 WEST CALDWELL, N. J. 07007
N.Y.C. 212 BE 3-0034 • N. J. 201 CA 6-3228

MORRIS CENTRIFUGAL PUMPS

November 2, 1966

U. S. Army Engineer District, Philadelphia
Corps of Engineers
Custom House
2nd and Chestnut St.
Phila., Pa. 19106

Attention: Mr. Adolph W. Mohr, P.E.
Asst. Chief, Plant Branch

Re: Booster Pumping Stations
Delaware River
Our Ref: I-1208-P

Gentlemen:

We are pleased to offer our thoughts and recommendations covering pumping equipment on booster pumping stations for future operation along the length of the Delaware River from Philadelphia to the river mouth.

The present operation for removal of river silt, sand, etc. utilizes a dredge which disposes of the material at nearby disposal areas. Through the years these areas have in some cases become obsolete due to lack of space and in others the property involved has become more expensive to prohibit its use as strictly a disposal area.

As we understand it the economics involved in dredging the river with ocean going hopper dredges and disposing at sea is prohibitive and thus the possibility of setting up booster pumping stations along the length of the river for final disposal at remote and still inexpensive locations.

One problem that immediately rises is how far can we pump between stations to minimize the stations and equipment.

You have used the Darcy-Weisbach formula for calculating pipeline lengths $\left(L = \frac{hf \times D \times 2g}{f \times V^2}\right)$ where "D" is in feet of pipe I.D., "V" is in feet per second of pipeline velocity, "hf" is equivalent to the pump T.D.H. and "f" the friction factor is .02. For 16" I.D. pipe and 231' TDH, you have come up with a pipeline length of 6890' per pump.

We have used for years the Hazen-Williams formula for calculating our friction losses in pipelines. Tests run on 12" and 16" dredgepipe of spiralweld or seamless steel construction

on sand equivalent to Jones Beach sand have indicated C value for Hazen and Williams of between 140 and 150.

To be conservative on similar dredge pump applications involving seamless steel or spiralweld steel pipe we use a value of C=130.

The Darcy-Weisbach calculations are equivalent to an H-W value of C=115 which, I feel, is too conservative and we will base our calculations to follow on C=130.

The critical carrying velocity for the material to be handled has been determined by you to be somewhat below 12 ft. per second and 12 ft. per second should be used for design. This velocity in 16" I.D. pipe is equivalent to a capacity of 7540 G.P.M.

A capacity of 7540 G.P.M. uses a friction factor at C=130 of 2.67 ft/100 in 16" I.D. pipe.

For a capacity of 7540 G.P.M. we would select a 14" pump. A 12" pump would have an excessive high velocity. A 16" pump would be operating too far to the left of peak efficiency for optimum performance.

The next problem is to determine the best head at which to operate this 14" pump. Our 14GMA47 dredge pump is capable from a hydraulic as well as mechanical design at running at 600 RPM and developing 290' T.D.H.

Experience has shown that on applications where high speed pumps are employed at peripheral speeds in excess of 6500 ft/min. we have experienced excessive pump wear. As a criteria we would recommend limiting the pump peripheral speed to 6500 ft/min. In the 14GMA47 this is equivalent to a pump rotating speed of 528 R.P.M. and a corresponding T.D.H. at 7540 G.P.M. of 220'

Based on the above, each pump will be capable of handling 8240 ft. of 16" I.D. pipe and with two pumps per station there would be 16,500 ft. between stations or stations spaced approximate every 3 miles apart.

Enclosed please find performance curve NY 66-10-25.

For a density of 1200 grams/liter, we would recommend using a 1000 HP motor for driving these pumps, although you might get by with 900 HP.

The 14GMA47 heavy duty dredge pump as described by Bulletin 193 enclosed, with hard metal wearing parts construction,

structural steel subbase for pump, motor and reduction gear including Falk couplings, a Falk 112071 Herringbone reduction gear with a 3.38:1 ratio and 1000 HP, 1800 RPM, 3 phase 60 cycle, 2300 volt open dripproof would rotor motor is $54,000.00 net per unit.

Weight approximately 57,000#.

If a standard squirrel cage motor is used, deduct $11,000.00 from the above.

We recommend variable speed pumps for this operation to enable us to balance the system, If the feed is constant from the dredge to the booster system, constant speed motors can be used.

Delivery on the above units would be six (6) months.

Each pump stuffing box will require clean water at a rate of 300 GPM. The first-stage dredge pump will require a pressure of 110 psi and the second-stage pump, 220 psi, to properly lubricate the stuffing box.

We trust the above information will be of value to you in preparing your estimates for this large project and we would welcome the opportunity to disucss the matter in more detail at a later date.

Very truly yours,

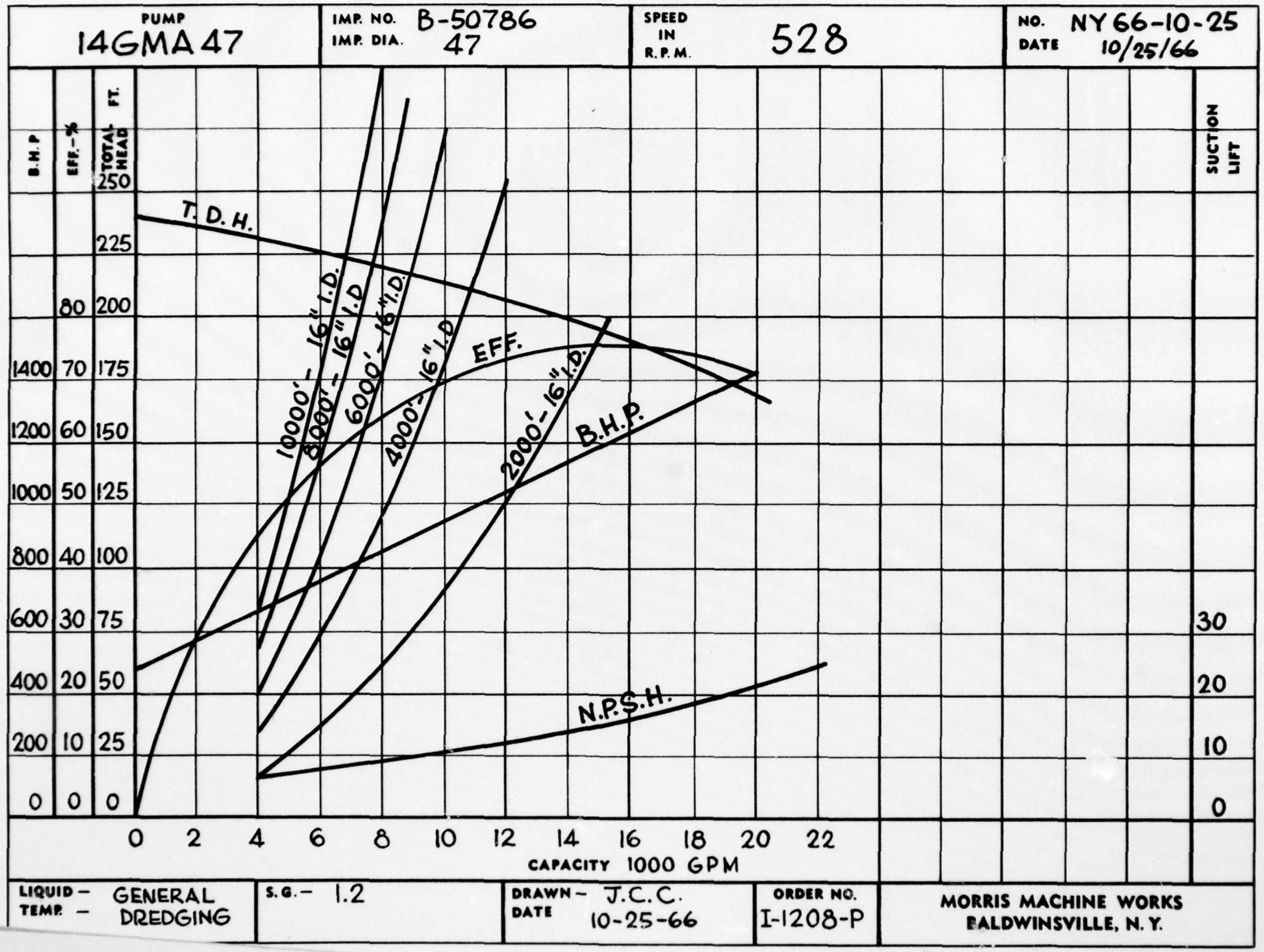
BRANN & CARY, INC.

J. C. Cary

J. C. Cary

JCC/asc

Enclosure


PUMP 14GMA47
IMP. NO. B-50786
IMP. DIA. 47
SPEED IN R.P.M. 528
NO. NY66-10-25
DATE 10/25/66
B.H.P.
EFF.-%
TOTAL HEAD FT.
SUCTION LIFT
T.D.H.
EFF.
B.H.P.
N.P.S.H.
10000' - 16" I.D.
8000' - 16" I.D
6000' - 16" I.D.
4000' - 16" I.D
2000' - 16" I.D.
CAPACITY 1000 GPM
LIQUID - GENERAL
TEMP. - DREDGING
S.G. - 1.2
DRAWN - J.C.C.
DATE 10-25-66
ORDER NO. I-1208-P
MORRIS MACHINE WORKS
BALDWINSVILLE, N.Y.

APPENDIX C

COST ESTIMATE FOR INSTALLATION AND OPERATION

COST ESTIMATE FOR INSTALLATION AND OPERATION OF A 100,000 FOOT PIPELINE

Procurement of 100,000 ft. of pipe @ \$5.85/ft. (16" I.D., 1/4 wall, 40 ft. sections 1 plain end, 1 female end, spiral welded, \$234/section from Armco)	\$600,000
Installation of above pipe @ \$2/ft (See Note 1)	200,000
Procurement of rehandling unit	300,000
Procurement of 8 booster stations @ \$100,000/station (one pump unit is spare)	800,000
Installation of dredge and boosters @ \$10,000/installation (See Note 2)	90,000
Procurement & install. of water pump & line to disposal area	100,000
Procurement & install. of instrumentation from dredge to boosters	70,000
Procurement & install. of pump sealing water equipment	80,000
Procurement & install. of floating line, handling equipment, etc.	100,000
Contingencies (Approx. 25%)	625,000
Say \$3,000,000	\$2,965,000

(1) Equipment amortization cost:

Pipeline cost $= \dfrac{\$800{,}000}{27{,}000{,}000 \text{ cu. yd.}}$ (See Note 3) — \$ 0.030/c.y.

Pump wearing Part Cost $\dfrac{(\$160{,}000\ (\$10{,}000/\text{pump in oper.})}{15{,}000{,}000 \text{ cu. yd.}}$ (See Note 4) — \$ 0.011/c.y.

Remaining $= \dfrac{(\$3{,}000{,}000 - \$960{,}000)}{70{,}000{,}000 \text{ cu. yd.}}$ (See Note 5) — \$ 0.029/c.y.

Sub Total — .070/c.y.

(2) Electric power cost:

1,300 KWh/hr station x 24 hrs/day x 300 days/year x 8 stations/line = 75,000,000 KWh/year

@ \$0.006/KWh, yearly power cost = \$450,000/year or 7,000,000 c.y.

$\dfrac{450{,}000}{7{,}000{,}000}$ = Sub Total = \$0.064/c.y.

(\$0.006/KWh for 13,200 V service and \$0.008/KWh for 4,160V service was obtained from Phila.. Electric Co.)

(3) Personnel cost: (7 days a week operation)

5 foremen	$45,000/year
5 operators	40,000/year
5 repairmen	36,000/year
10 dump men	60,000/year
	$181,000/year

(4) $\frac{\$181,000}{7,000,000}$ = Sub Total = $0.026/c.y.

Disposal Area preparation plus pipe line handling at end of line is estimated at $0.03/cu. yd. (See Note 6)

Summary

1. Equipment Cost	=	$0.070
2. Power Cost	=	0.064
3. Labor Cost	=	0.026
4. Disposal area cost	=	0.03
		$0.190/ cu. yd. for a 100,000 foot line

Unit cost equals about .01/cu. yd./ per mile of transport.

NOTES

1. No real estate charge included. It is assumed right of way can be obtained at nominal cost on electric company right of way or gas company right of way dependent on power to be used.

2. Philadelphia Electric Company advises that power lines to the booster stations would be provided at power company expense.

3. Wear Factor for Pipe
80,000,000 c.y. wore out the 5/8" wall floating line in Delaware River Maintenance Work
Assuming that 1/16" remaining wall renders a pipe useless, implies that the life of a 1/4" pipe would be 80,000,000 x $\frac{3/16}{9/16}$ 27,000,000 c.y.

4. Wear Factor for Pump Wearing Parts:

The wearing parts of hopper dredge pumps usually last three years and work 50% of this time. The wearing parts of the rehandling equipment working 75% of the time will last 2 years or approximately 15,000,000 c.y.

5. Wear Factor for Remaining Equipment:

It is assumed that all rehandling equipment not covered in the foregoing will have a life of ten years or 10 x 7,000,000 = 70,000,000 c.y.

6. From experience data on actual operations.

7. All costs are based on 1967 price levels.

APPENDIX D

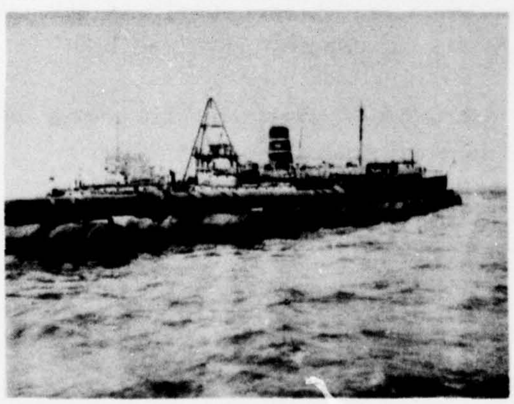
PIPE MATERIAL EVALUATION

PURPOSE: The purpose of this investigation was to evaluate the wear properties of several different types of steels and liners used in fabricating pipelines. Included in the evaluation of this pipeline was a determination of the wear pattern exhibited by the pipe. It was expected that this investigation would confirm or alter the Government specifications used for the procurement of dredge piping.

TEST DESCRIPTION: In March 1967 an experimental pipeline was installed adjacent to MOORING BARGE #2. It was part of the floating pipeline used in pumping dredged material to on-shore disposal areas. The experimental line was constructed of ten sections Four of these sections were 20 feet long, lined with abrasive resistant materials, The thickness of these liners was 1/4"; cemented or applied to steel cylinders 3/8" thick. One test section 20 feet long was lined with cement 1/2" in thickness. The other five sections were 40 feet long constructed of steels, 5/8" in thickness, meeting different specifications. All the pipe sections had an initial inside diameter of 28". Details of the materials used are presented in Table I-D. Before being placed into service the weights of the unlined sections were recorded.

All the material dredged by the Government Hopper Dredge COMBER from the Delaware River and Chesapeake and Delaware Canal was pumped to shore disposal areas through these test sections. The various dredging assignments are outlined on Table II-D and furnished a total of over 11 million cubic yards of inplace material averaging 1300 grams/liter in density. The material was rehandled by the addition of diluting water at approximately 1075 grams/liter density, which increased the effluent handled to 44 million cubic yards. This material dredged from the river is uniformly fine graded matter with 90% of the material passing a 200 mesh screen. In September 1968 the ten pipe sections were removed temporarily from the floating line and evaluated.

TEST RESULTS: Visual inspection of the pipeline revealed that all the lined sections failed. (Cement lined section had failed three weeks after the start of the test). At the bottom of each lined section a grove or channel was worn away as seen in Figure 1-d.



Experimental pipeline in service.

Rubber lined pipe after 18 months of service.

Figure 1-d

TABLE I-D

SECTION NO.	MATERIAL TESTED
1.	United State Steel T-1 type A, a steel having a high impact abrasion resistance and atmospheric corrosion resistance.
2.	Steel meeting specifications set by A1S1-C-1038.
3.	Steel meeting specifications set by A1S1-C-1036.
4.	Steel meeting specifications set by A1S1-C-1027 and heat treated to assure minimum hardness of 300 BHN. (NOTE: This section was not painted with Red Lead paint as were the other sections tested).
5.	Rubber liner manufactured by B.F. Goodrich Company. This liner has minimum tensile strength of 3000 psi. minimum elongation of 450%, bond strength of 30 lb. linear inch hardness of 35 on the Shore A Scale and a specific gravity of 1.13.
6.	Rubber liner manufacturer by LaFavorite Rubber Company. This liner has an average tensile strength of 3250 psi., average elongations of 500%., bond strength of 30 lb. Linear inch, tear strength of 450 psi., hardness of 60/70 on the Shore Scale and a specific gravity of 1.12.
7.	Rubber liner manufactured by Goodyear Tire & Rubber Company. This liner has average tensile strength of 3000 psi., elongation of 450%, hardness of 605 on the Shore A Scale, and a specific gravity of 1.15.
8.	Plastic liner manufactured by Quelcor Incorporated. This liner has an average tensile strength of 2000 psi., elongation 325%, tear strength of 300 psi., hardness of 82 87 on the Shore A Scale, and a specific gravity of 1.30.
9.	Cement lined pipe manufacture by Armco Steel Corporation. This cement liner is really a mortar composition with uniformly graded fine sand. filler.
10.	Steel meeting specifications set by ASTM-A-242. This is the standard steel used for piping presently employed by the District.

TABLE II-D

MATERIAL DREDGED DURING TEST PERIOD

DATES	LOCATION	YARDAGE	IN SITU DENSITY
1 March 67- 4 April 67	C&D Canal, Closure structures Station 41+500 to Station 42+600	47,150	1340
3 March 67- 5 April 67	Delaware River, New Castle Range Station 226+000 to Station 233±000	532,169	1300
1 May 67- 5 May 67	Delaware River, Marcus Hook Anchorage Station 120+000 to Station 124±000	342,379	1270
5 April 67- 30 April 67 15 May 67- 28 May 67	Delaware River, Marcus Hook Range Station 117+000 to Station 125+000	815,620	1270
28 May 67- 14 June 67	Delaware River, Bellevue & Cherry Isl. Station 156+000 to Station 162+000	400,994	1300
20 July 67- 8 August 67	C&D Canal, Cut-off channel Station 41+000 to Station 42+800	79,734	1390
28 August 67- 29 August 67	Delaware River, Reedy Island Range Station 249+000 to Station 251+000	13,349	1700
24 August 67- 22 Sept. 67	Delaware River, Deepwater Point Range Station 198+000 to Station 206+000	911,170	1300
19 July 67- 24 July 67 22 Sept. 67- 11 Oct. 67	Delaware River, New Castle Range Station 227+000 to Station 233+000	1,395,633	1300
11 Oct. 67- 5 Nov. 67	Delaware River, Deepwater Point Range Station 191+000 to Station 198+000	752,225	1300
5 Nov. 67- 3 Dec. 67	Delaware River, Cherry Island Range Station 168+000 to Station 174+000	811,397	1290

TABLE II-D (Continued)

DATES	LOCATION	YARDAGE	IN SITU DENSITY
3 Dec. 67- 13 Dec. 67	Delaware River, Deepwater Point Range Station 189+000 to Station 195+000	263,247	1300
13 Dec. 67- 1 March 68	Delaware River, Marcus Hook Range Station 117+000 to Station 130+000	2,008,489	1270
1 March 68- 22 March 68	Delaware River, Chester Range Station 107+000 to Station 114+000	33,496	1500
1 March 68- 15 March 68 18 March 68- 22 March 68	Delaware River, Marcus Hook Anchorage Station 125+000 to Station 132+400	392,208	1270
23 March 68 26 March 68	Delaware River, Reach N, O, & P, Phila. Station 29+800 to Station 32+756	17,775	1410
11 April 68- 12 April 68	Delaware River, Marcus Hook Range Station 119+000 to Station 120+000	7,993	1270
22 March 68- 14 April 68	Delaware River, Reach M Station 32+756 to Station 36+000	225,249	1340
15 August 68- 16 August 68	Delaware River, Bulkhead Bar Range Station 208+973 to Station 212+364	32,503	1290
8 July 68- 10 Sept. 68	Delaware River, Marcus Hook Range Station 120+000 to Station 131+000	1,972,385	1270
19 Sept. 68	Delaware River, Tinicum Range Station 93+000 to Station 97+000	2,379	1800

The sides and tops of these sections also exhibited extensive wear and gouging caused by larger sized material passing through the line. Because of this obvious failure the lined sections were removed from the pipeline and no further consideration will be made on the practical use of linings in long distance pipeline.

The five sections fabricated from the different types of steel were reweighed and their wall thicknesses measured. The amount of wear at the top and bottom of the pipe, two feet from both ends, and the initial and final weight of each section are presented in table III-D:

TABLE III-D

Section No.	Initial Weight (Lb.)	Final Weight (lb.)	Wear Loss (Lb.)	East End of Pipe Top Wear (In)	East End of Pipe Bottom Wear (In)	West End of Pipe Top Wear (In)	West End of Pipe Bottom Wear (In)
1	8410	7835	575	.015	.065	.025	.080
2	8568	8011	557	none	.045	none	.045
3	8316	7879	437	none	.075	.015	.065
4	8228	7605	623	.035	.080	.035	.075
10	8576	8055	521	.015	.085	.015	.045

All sections exhibited a weight loss, however, a significant variation of the amount of wear was noted among the different sections; Section number 3, fabricated from steel conforming to A1S1-C-1036, had the least weight loss. Section number 4, fabricated from steel conforming to A1S1-1027 and heat treated to a minimum Brinell hardness of 300, experienced the most weight loss. Although the different types of steel behaved differently no characteristic of composition or treatment was isolated. Further investigation including chemical analysis and hardness testing is planned for several sections of the experiment pipeline.

In order to investigate the wear pattern of the pipe, the most worn section was cut in half and 16 micrometer measurements (one every 22.5 degrees) were taken of the wall thickness. The wear pattern determined from these measurements is represented in figure no. 2-d. It should be noted that the low point (the point of most wear) is not located at the bottom of the pipe. This is probably caused by a "snaking effect" of the material passing through the pipe. Another cross-section of pipe may have the low point at the bottom or on the other side of pipe. From this wear pattern, it is predicted that the pipe will fail after 240 million cubic yards of effluent material are passed through the pipe if not rotated. (It is assumed that pipe failure occurs when any point of its wall is reduced to a thickness of 1/16 of an inch). Figure no. 3-d shows the projected wear pattern of this section to failure.

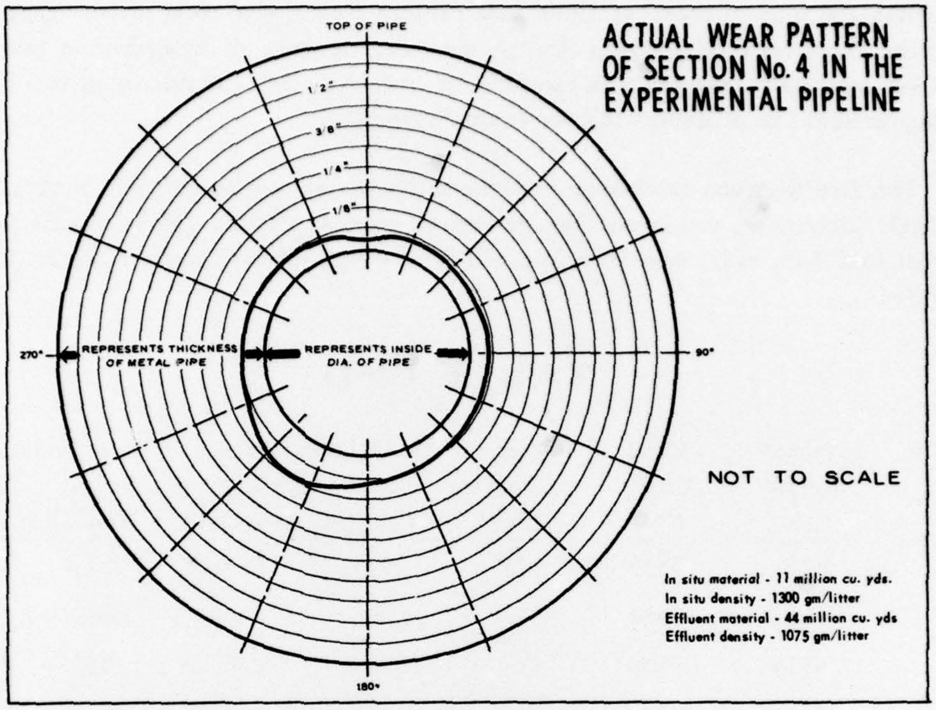


Figure 2-d

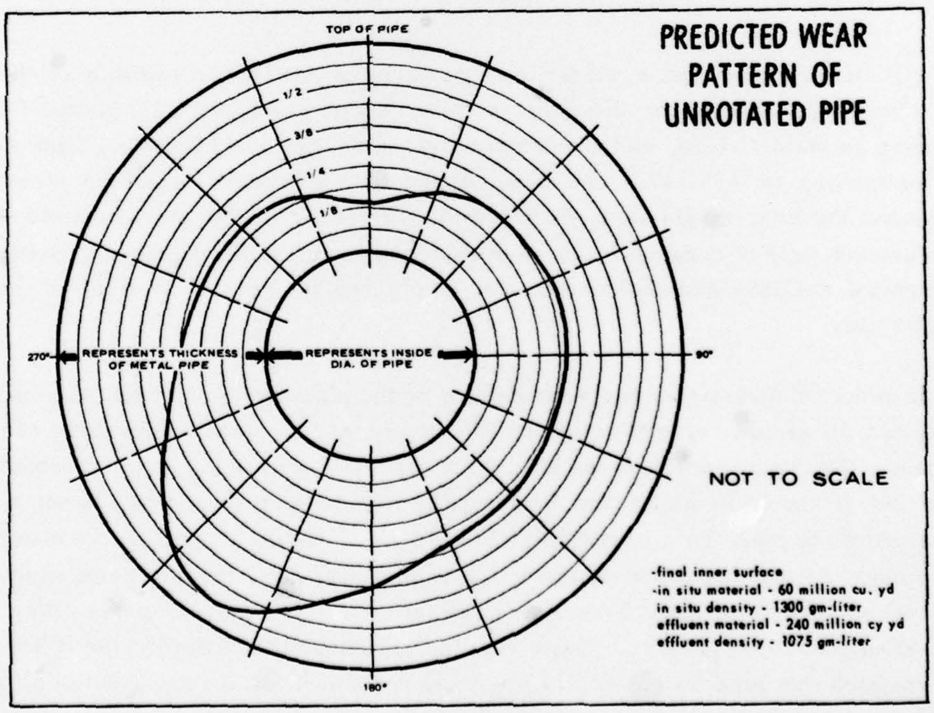


Figure 3-d

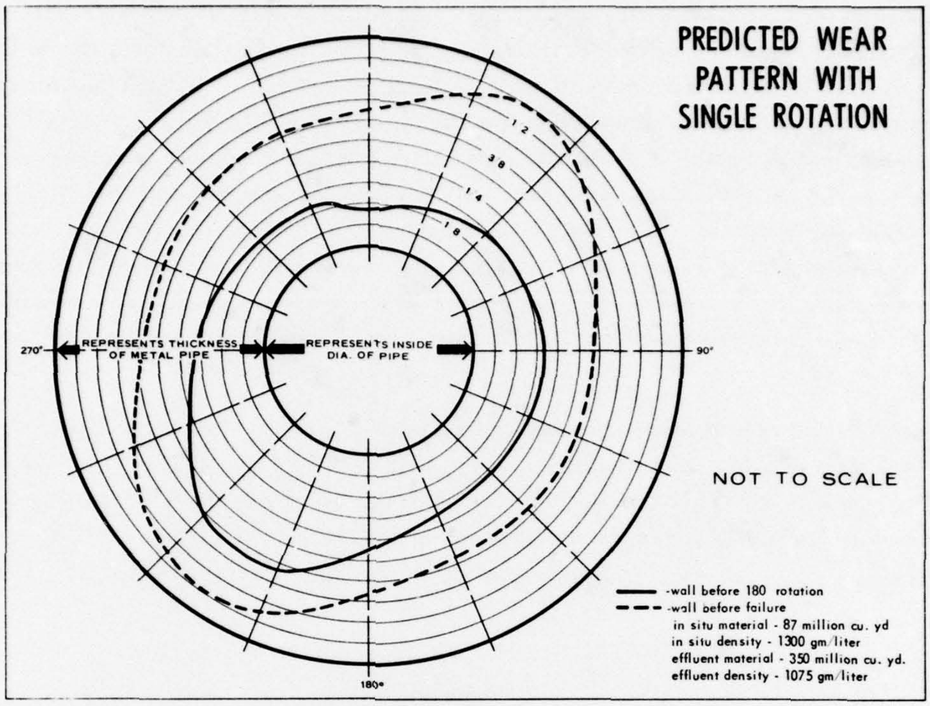


Figure 4-d

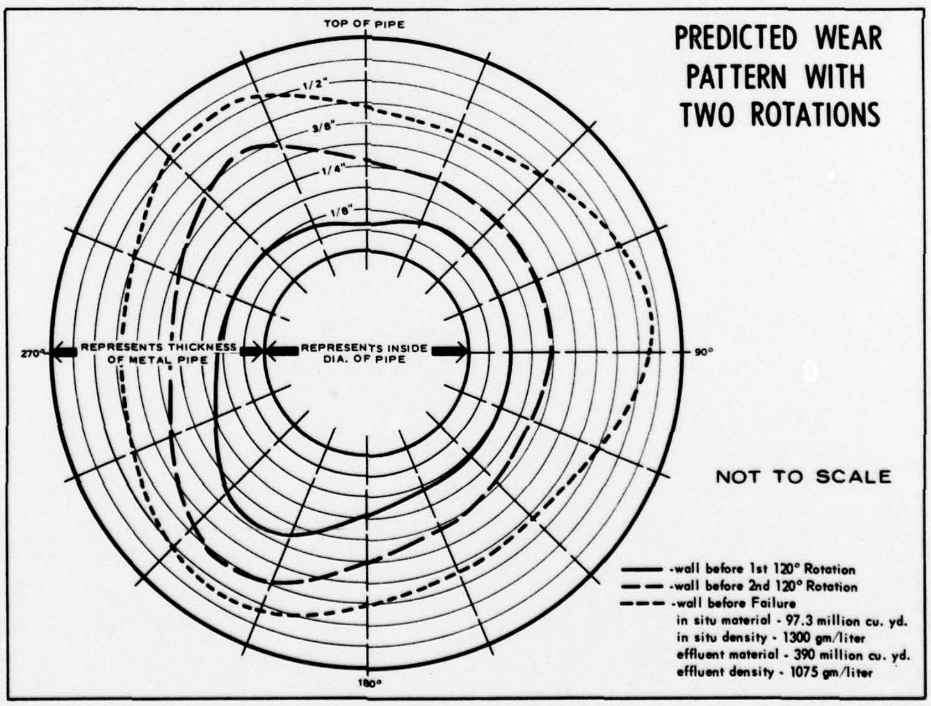
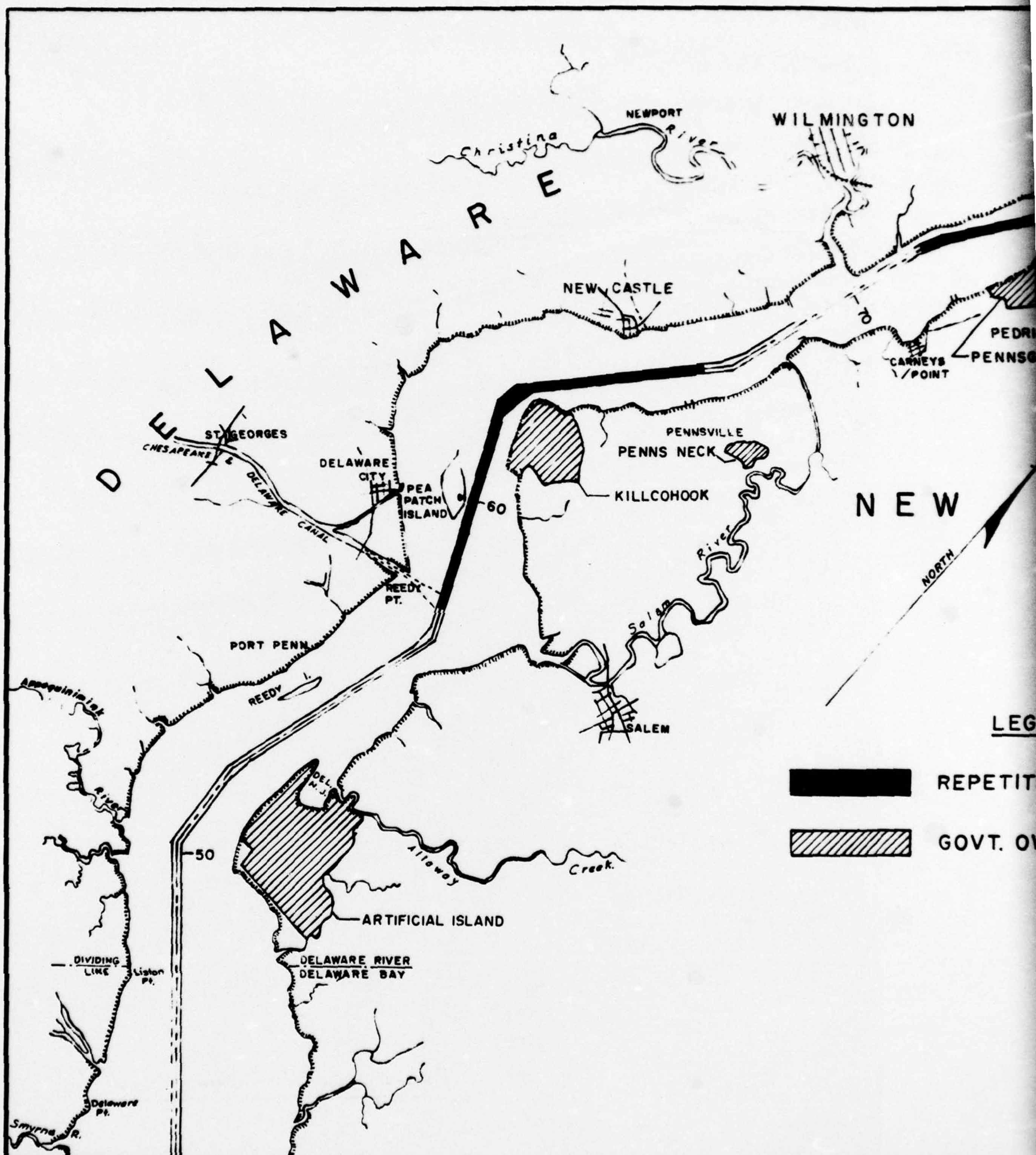


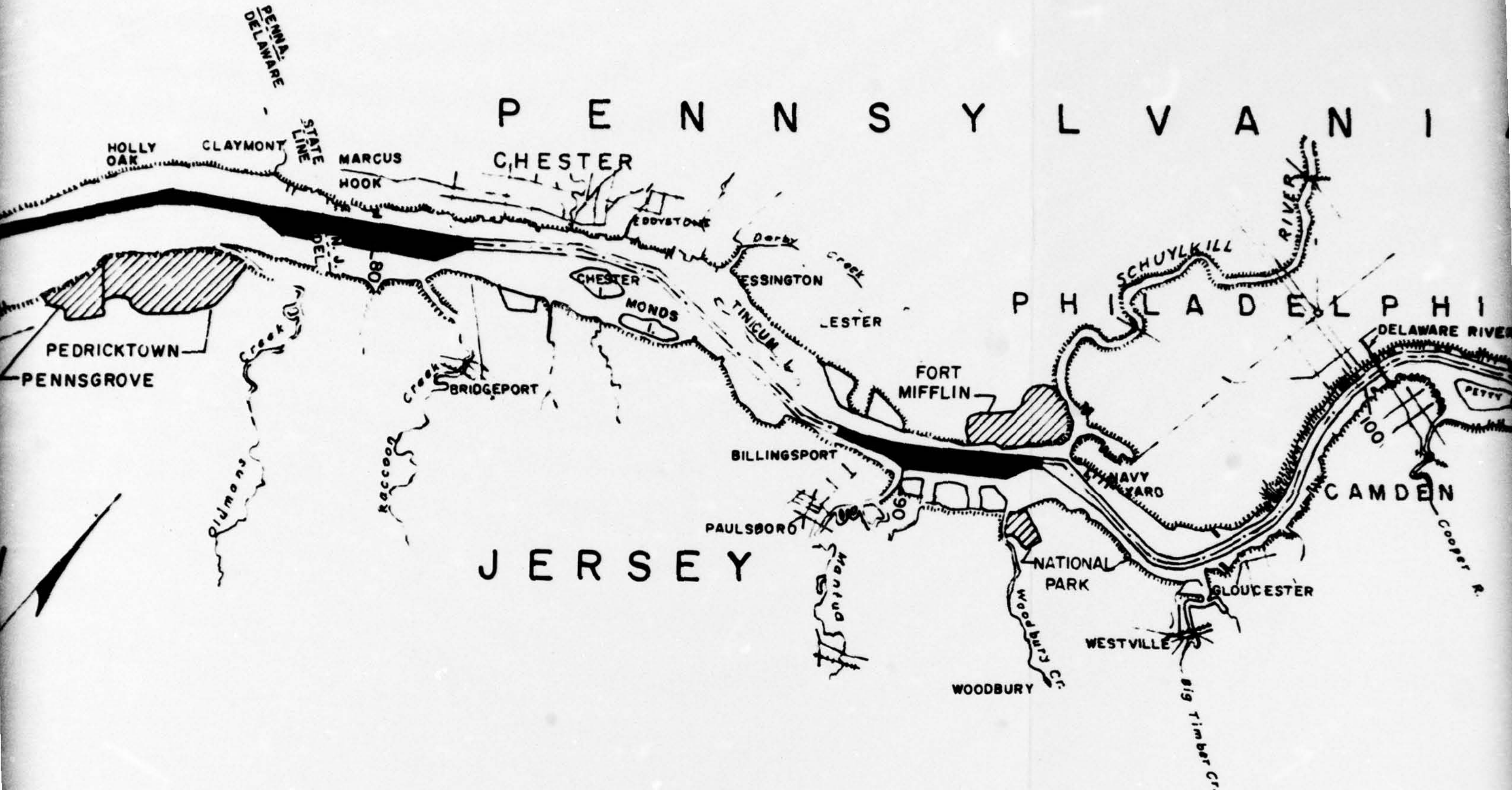
Figure 5-d

Rotation of a pipeline while in service would significantly increase its life. Assuming that the wear pattern is not appreciably altered when the pipe is rotated, the wall would not be worn to the critical thickness until 350 million cubic yards of effluent material have passed through it. This is based on a single rotation of 180 degrees after 175 million cubic yards of material pumped. Figure no. 4-d shows the predicted wear pattern under these conditions. It may be practical and economical to rotate a pipeline twice during its service in pumping dredging spoils. An estimated 390 million cubic yards of effluent material could be pumped through the 5/8 inch thick steel pipe if the pipeline is rotated 120 degrees after 130 million cubic yards are passed and again rotated 120 degrees after 260 million cubic yards are passed. See figure no. 5-d. It is believed not economical to rotate a pipe more than twice.

Most of the pipe used on shore in the disposal operation has a 1/4 inch thickness. We can predict one third as long service time as the 5/8 inch pipe. The wear characteristics will be similar; the only change is in the available thickness of the wall. Again using 1/16 inch wall thickness as the safety limit the available wear thickness is 3/16 of a inch. Therefore $\frac{3/16}{9/16} = 1/3$; where 9/16 is the available wear thickness of 5/8" pipe.



DELAWARE
NEWPORT
WILMINGTON
Christina
River
NEW CASTLE
PEDRI
PENNSG
CARNEYS POINT
ST. GEORGES
CHESAPEAKE & DELAWARE CANAL
DELAWARE CITY
PEA PATCH ISLAND
60
PENNSVILLE
PENNS NECK
KILLCOHOOK
NEW
NORTH
Salem
River
REEDY PT.
PORT PENN
REEDY I.
SALEM
Appoquinimink
River
DEL. N.J.
50
Alloway
Creek
ARTIFICIAL ISLAND
DIVIDING LINE
Liston Pt.
DELAWARE RIVER
DELAWARE BAY
Delaware Pt.
Smyrna R.
LEGE
REPETITI
GOVT. OW



LEGEND	NAME OF MAJOR SHOAL	ANNUAL SHOALING RATE
EPETITIVE SHOAL AREAS	NEW CASTLE	1 800 000 C.Y.
OVT. OWNED DISPOSAL AREAS	MARCUS HOOK	4 000 000 C.Y.
	MIFFLIN	1 500 000 C.Y.

SCALES

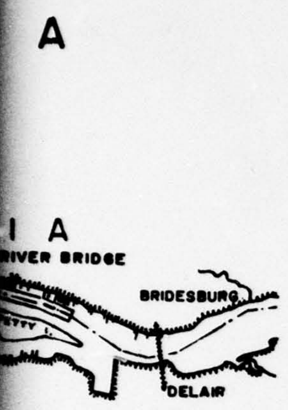
5000 0 5 10 15 20 25 30 35 000 FEET

1 0 1 2 3 4 5 6 STATUTE MILES

LON

U

2



LONG RANGE SPOIL DISPOSAL STUDY

DELAWARE RIVER
MAJOR SHOALS

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 1